Concrete Construction

ITS FIRE-PROOF QUALITIES

AND FURTHER DATA AS
TO COMPARATIVE COSTS

ISSUED BY
ASSOCIATION OF AMERICAN PORTLAND CEMENT MANUFACTURERS

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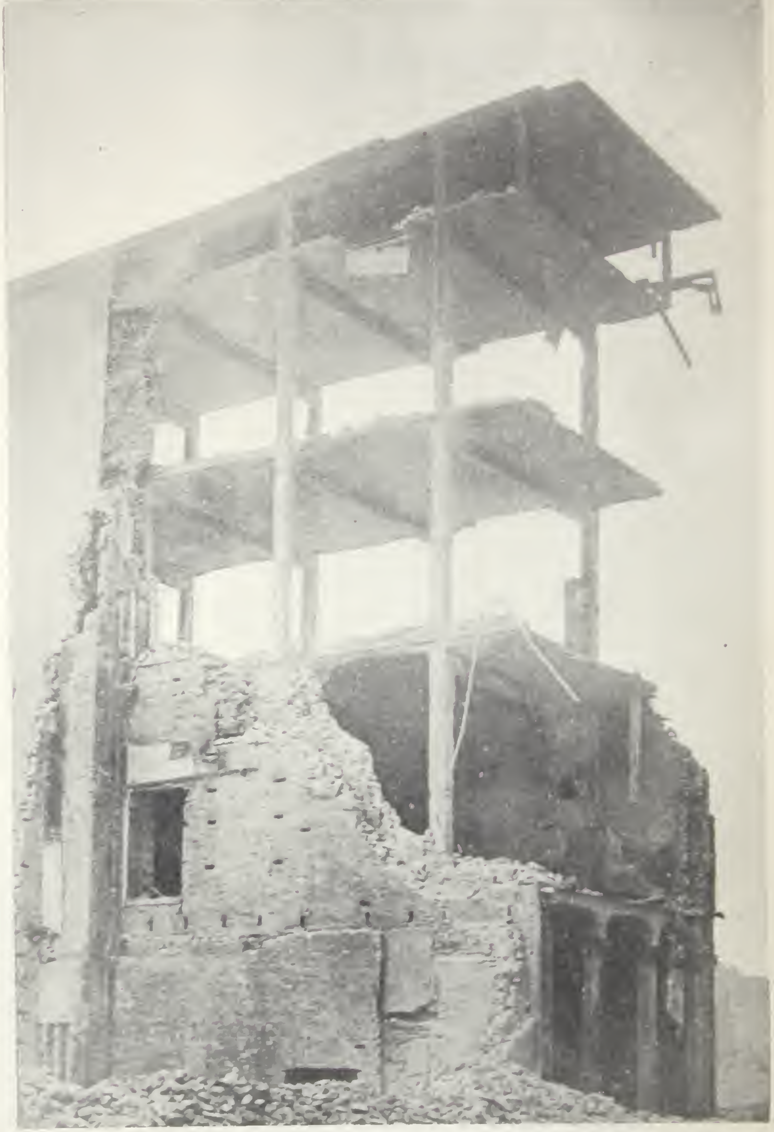


FERRO CONCRETE STRUCTURE STANDING AFTER THE FIRE.

FOREWORD.

This little pamphlet is issued in the hope that it may serve a useful purpose in marshaling into readily accessible form the records of some of the most interesting developments in concrete construction during the past year.

The following articles are reprinted from the *Cement Age*, because we believe that they are of permanent importance and because the supply of the numbers containing them has been exhausted. The publication of the report of the Insurance Engineering Experiment Station on the conflagration in Baltimore aroused wide-spread interest in concrete construction in building, manufacturing and insurance circles. So keen was this interest that in order to answer the questions addressed to him in reference to concrete construction, Mr. Edward Atkinson wrote an open letter to those interested in concrete construction, asking for specific data on which to base estimates of the comparative cost of concrete and slow-burning mill construction, and also as to the ability of concrete to withstand vibration strains.

Besides the report on the Baltimore fire will be found answers to Mr. Atkinson's questions prepared by the *Cement Age*.

No man ever earned his right to a reputation for judicious conservatism more fully than has Mr. Edward Atkinson, and no man ever fitted his niche in the scheme of things more perfectly.

The position of Director of the Insurance Engineering Experiment Station is one in which any man who might be swayed by his enthusiasm (for anything save hard work) would be utterly unfitted.

The excerpts quoted herewith form his introduction to the report on the Baltimore fire, may therefore be accepted as irreproachable authority.

After criticising more or less severely various forms of construction, Mr. Atkinson takes up the question of concrete in these words:

"Well-made concrete encasing steel proves to be most fully a fire resistant, when it is made with true Portland cement, rammed and tamped in a proper manner. It fortunately happens that a well-made concrete of this kind is subject to a law of expansion and contraction under heat so nearly identical with that of steel as to assure its position being maintained under high and varying temperatures. It will be remarked that the temperature in this conflagration must have reached a higher point in many of the buildings of ordinary construction than it did in the steel-framed buildings. In the former, many examples of melted iron and steel were found; in the latter, few traces of a temperature reaching these melting points."

In this paragraph lies the very crux of the whole matter, which is, that *the co-efficient expansion under heat of steel and concrete is practically identical.* It is entirely probable that some other material, provided it is used exclusively in the erection of a building would prove as perfectly fireproof as does concrete. Discussion on this point is, however, purely acedemic; because, no material has been found, nor is one likely to be found, which will obviate the necessity of using steel in some form as a frame-work. It will not, however, be the province of the *Cement Age* to decry other methods of construction If the simple presentation of the facts relative to concrete construction fails to convince the reader of its merits, why then he must go unconvinced.

REPORT SUBMITTED TO THE INSURANCE ENGINEERING EXPERIMENT STATION, EDWARD ATKINSON, DIRECTOR, ON THE CONFLAGRATION IN BALTIMORE.

By PROF. CHARLES L. NORTON.

I visited Baltimore five days after the beginning of the fire and spent three days in looking over the field in a general way, interviewing eye-witnesses, and making a rather limited examination of the ruins largely from the streets. Ten days later I made a second visit of four days, spending the time almost wholly in studying the conditions of the so-called fire-proof buildings, examining them all except the *Herald* building. The details of the fire and the general description of the condition of the district after the fire, have been so thoroughly published as to call for no further repetition here, and it is my purpose to call attention only to the more technical lessons to be learned from this conflagration.

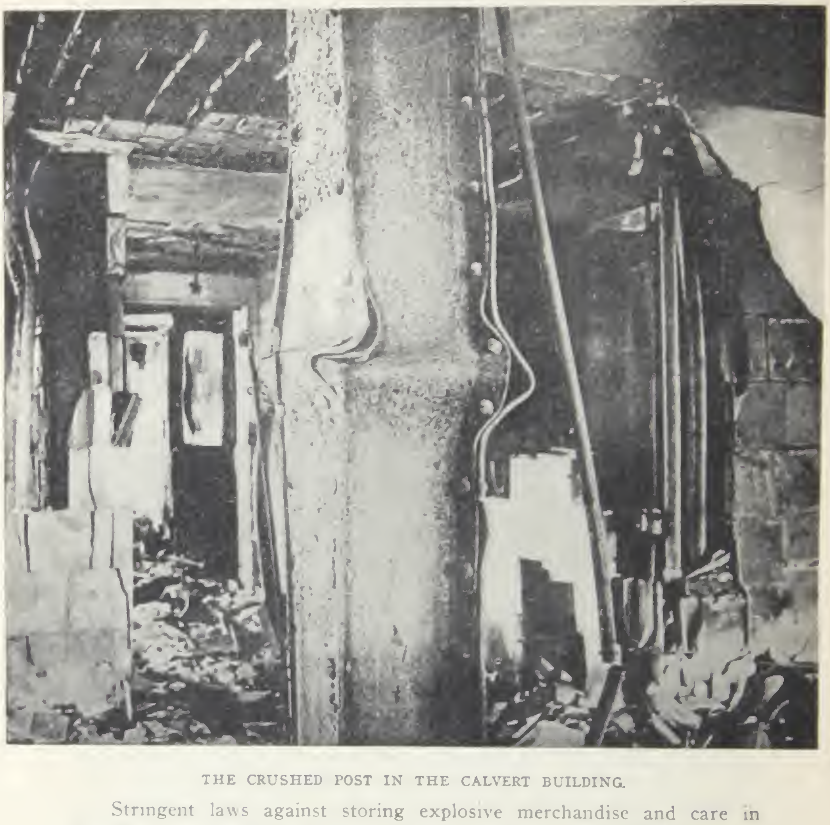
A study of the conditions prevailing in the portions of Baltimore which were recently destroyed by fire, and of the structures in this district after the fire, leads to two general lines of suggestion for future safety of similar districts in cities now built or to be built.

The first thought that occurs to one in looking over the situation is the similarity of conditions prevailing in almost all large cities in the matter of lack of preventive measures in retarding fire spread from building to building, the lack of protection against exposure hazard. The second thought brought home by the towering remains of the tall steel-frame buildings is the failure of the word "fire-proof" to give any proof of its right to exist as applied to such buildings.

The danger of spread of fire through the whole of such a district needed no new emphasis. Boston, Chicago, Paterson, and other cities had shown that none of the preventive measures in use in such cities would avail against a fire started during a gale of wind in a district composed largely of buildings of inferior construction. What happened in Baltimore is likely to happen in New York or Boston if once a fire gets well under way. The danger is not so great, perhaps, in some other cities as it was in Baltimore, but its presence must be admitted.

The measures to be adopted to prevent the possible conflagration spread in cities have been enumerated by abler pens than mine, but I will venture upon a few suggestions: First, remove from these crowded cities the greatest cause of quick spread of fire, in the shape of explosive material. It has been said that explosions of chemicals occurred in the early part of this fire, but whether or not this was really the case or whether there was a series of so-called hot-air explosions from the products of distillation, it seems clear that something in the nature of an explosion scattered the fire.

As is well known, the products of distillation in a slow fire smoldering for some time before becoming rapid in its spread, may, when mixed with air, become explosive. The opening of a door or breaking of a window may cause a draft that leads the flames toward the smoky mixture and starts the explosion, known to the firemen as a "hot air" explosion. Sprinklers and ventilation and stops in vertical openings tend to minimize this danger.



THE CRUSHED POST IN THE CALVERT BUILDING.

Stringent laws against storing explosive merchandise and care in installing ventilation systems, thermostat systems and sprinklers will tend to minimize the danger of early spread of fire by explosion.

Unless violently scattered as by an explosion, fire spreads through such a district by the carrying of sparks, by direct contact of flame, and by radiation across open spaces. Protection against all these dangers is to be sought by means of non-inflammable roof materials, shutters, and wired glass, in metal or metal-covered frames for openings, and roof hydrants.

Fire has apparently in this case found its way from building to building through doors and windows and through roofs which offered but slight resistance. There were buildings in this district equipped with tinned and sheet-iron shutters and some with other protective devices,

TERRA-COTTA CEILING OF THE CORRIDOR—CONTINENTAL TRUST BUILDING.

but few or none withstood against the enormous volume of flame and hot gases coming from the majority of partially protected or unprotected risks. There is nothing new in this, but it is a condition so common and so dangerous as to bear repeated references.

I am satisfied that with roof hydrants having a good supply of water, and the universal use of wired glass and tinned shutters and metal-covered sash in this district, the Baltimore fire of 1904 had been relatively a small conflagration. And, further, the systematic use of these three preventive appliances and sprinkler systems in other cities where they are not in use would greatly decrease the conflagration risk.

SHOWS CONDITION OF A LARGE PART OF THE TERRA-COTTA FLOOR ARCHES

The second and more interesting line of suggestion comes from a minute study of the condition of some seventeen so-called "fire-proof" buildings in the burned district. Some of these are untouched. Some are ruined. Some are sadly damaged. Let us see why their conditions are so different, and why some fared so badly.

It is apparent at once that some of the buildings are intact in large part because of their having been less vigorously attacked by the fire than were the others and for no other apparent reason.

These buildings being low, surrounded by taller neighbors, or situated on street corners, seem to have been actually jumped over by the wave of combustion. There is ample evidence that the outside of these build-

ings did not rise in temperature to the igniting point of wood or paint. On some of them not even the skylights are broken, and an almost incredibly small amount of damage was done to their exterior. In most cases the buildings may be said to have been without a severe fire trial.

A second group of fire-resisting buildings includes those which have been well described by the word "monumental." The Court House and City Hall offer examples of this type, being heavy stone buildings, with comparatively few window openings. Offering a small area for the en-

A ROOM IN THE CALVERT BUILDING, SHOWING FAILURE OF PARTITIONS.

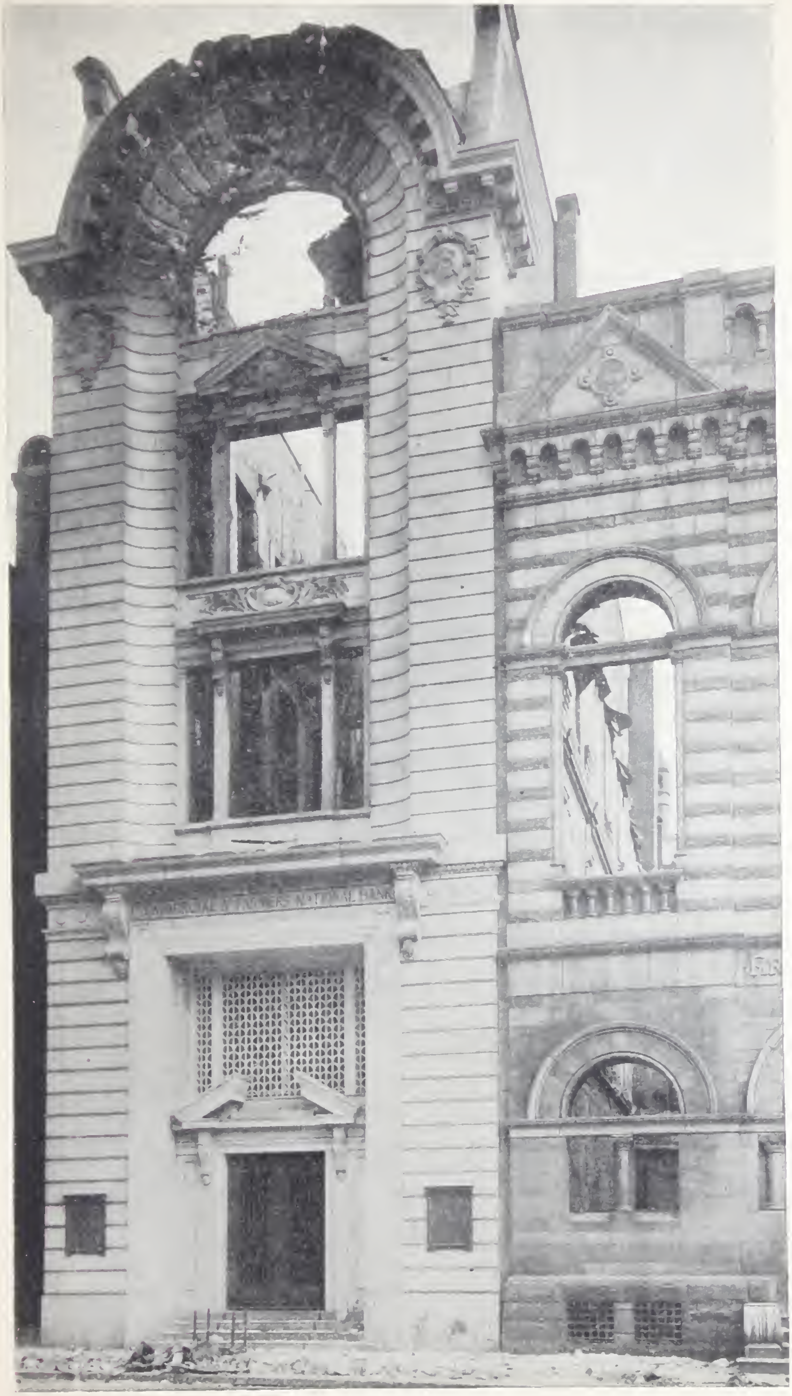
trance of fire and a non-inflammable exterior, these buildings withstood great heat, with no damage except from the spalling of the stone and charring of window frames. It should not be assumed, however, that the fire was driven toward these buildings with such fury as that which it expended on some of the steel-frame buildings, as accounts indicate that a change in the wind diverted the fire from them at the most opportune time. On the whole, these monumental buildings demonstrate the effectiveness of a minimum window area in reducing the danger of ignition rather than anything else. They further call attention to the

frailty of stone. The modern steel-frame construction, popularly called "fire-proof," was exemplified by some half-score of buildings in the edge and center of the burned area. These buildings furnish material for much study, and, from their defects as here demonstrated, I have no doubt

INTERNATIONAL TRUST COMPANY, IN PART CONCRETE STEEL; SKYLIGHT CRUSHED BY FALL OF NEIGHBORING WALLS.

that we may learn much that will go far to prevent even the partial destruction of such buildings built in the future.

The general condition of the steelwork itself is apparently good, except in a few instances. Neither the fire, nor corrosion preceding the fire, has sensibly affected it, if we may judge from its appearance. The "fire-proof" buildings of steel-frame construction show in general failures



COMMERCIAL AND FARMERS' NATIONAL BANK. STONE CONCRETE BELOW BANK ROOM, WOODEN CONSTRUCTION ABOVE.

along the same lines. Where the walls are substantial and of good red brick, they stood the test fairly well. There was some spalling and in some cases a crumbling, but good red bricks seems to have lived up to their earlier reputation. Where brickwork of a lighter color, ornamented with terra-cotta, was used, considerable more damage was noticeable, especially after the slight snow storms of the week following the fire. Stone trimmings, almost universal on the lower fronts, demonstrated the unfitness of that material beyond all question. Granite, marble, sandstone, and limestone all fared about alike, even when, as near as can be ascertained, very little or no water was thrown upon it. In general, all outside wall material suffered, but brick much less than the rest.

It has already been said that the steel frames themselves appeared in good condition. Exceptions to this may be found in the Equitable Building and in the upper stories of some of the others. None of these frames, however, collapsed, and none are likely to do so, though some posts and beams were bent or crushed and some will need to be replaced in nearly every one of the steel-frame buildings. The light steel frame of the somewhat older Equitable Building is seriously injured, and a considerable amount of reconstruction is needed here. Posts are bent and sagged and beams are badly deflected. It is probable that this light frame was subjected to a great strain from the falling of the safes after the plank top floor burned through, the arches of terra-cotta not being strong enough to carry their weight.

The steel frames will need careful examination to note possible distortion or weakening. In general the frames are not injured by more than 10 per cent., and in some cases by a much less amount, though in the Equitable Building the loss to the steel would seem to be between 50 per cent. and 75 per cent., or even more.

The posts and beams in about all these buildings were covered either with terra-cotta or with "lime-teil," a material whose composition appears to be in the nature of a plaster and cinder mixture. Generally the covering served its protective purpose well, but was itself destroyed or badly damaged. A very large percentage of the terra-cotta and lime-teil block must be replaced, and it is the general, almost universal, condition that the beam covering of the flanges is gone. The loss of terra-cotta beam and post coverings was at least 75 per cent.

The partitions of terra-cotta and lime-teil are very largely destroyed and the unfitness of these materials for this purpose seems clear. Many partitions have fallen and more are in such condition that they must be replaced. Much of the lime-teil is softened and the terra-cotta is cracked or broken and the bond between blocks is loosened. If metal lath partitions were in existence to any great extent, they failed as well, for few were in evidence in good order.

The floor arches of many different spans and of different details of construction, but in the main of terra-cotta or lime-teil, show much the same sort of distress as the partitions. The bond between the tiles is broken, quite generally, and the tiles themselves are cracked and broken

in great numbers. The lower face or soffit of the tiles has split off over large areas, and 50 per cent. or 60 per cent. of the terra-cotta floor construction will, I fear, need to be replaced or reinforced.

Where concrete floor arches and concrete-steel construction received the full force of the fire it appears to have stood well, distinctly better than the terra-cotta.

The reasons I believe are these:—First: because the concrete and steel expand at sensibly the same rate and hence when heated do not subject one another to stress, but terra-cotta usually expands about twice as fast with increase in temperature as steel and hence the partitions and floor arches soon become too large to be contained by the steel members which under ordinary temperature properly enclose them. Under this condition the partition must buckle and the segmental arches must lift and break the bonds, crushing at the same time the lower surface member of the tiles. Especially in the Calvert Building I found evidence which leads me to believe that not an excessive temperature, but the differential expansion under a moderate high temperature of the terra-cotta of the top and bottom members and of the enclosing steel, is responsible for the general failure of the terra-cotta partitions, beam-covering, and floor arches. Secondly: Mr. Gray suggests that there is a similar unequal expansion of the top and bottom faces of the separate tiles, which causes the lower faces to expand and shear off. Evidences of this were found everywhere.

Further examination of the expansion phenomena points to them as the main source of distress to the whole beam and post covering, floor, arches, and partitions. Most of the fallen terra-cotta partitions and the floor blocks were still hard and had a clear ring when struck, though cracked and broken. There was no evidence of any such temperature as that at which the terra-cotta had been baked originally, and the material of the blocks could not have been altered chemically. It will be readily understood that the thin walled hollow tiles would become heated upon one side much more quickly than would the equivalent area of a solid partition of brick or concrete. Terra-cotta, cinder concrete, and stone concrete all have about the same heat-absorbing power, or specific heat, and hence the heavier and more solid the partition or floor, in other words, the more material there is in it, the slower will be its rise in temperature and its subsequent expansion.

I question whether any floor, containing so little material on its outer faces as did these hollow blocks, could remain sufficiently cool in this fire to avoid serious injury from expansion.

The minor details of the structure and finish fared badly. Wood is not in evidence except in secluded corners. Marble, slate, plaster, and in fact all similar surfacing material suffered to the point of destruction. The cast-iron stair frames and rails stood remarkably well in most instances.

The building of United States Fidelity and Guarantee Company is an interesting example of reinforced concrete in the district As near as I could ascertain, it was subjected to a severe fire and I found evidence

of temperatures up to the softening point of cast iron. The condition of the lower part of the structure and apparently of the whole structure showed the great fire-resisting powers of this type of building. It is of especial interest that the Experiment Station made a preliminary test on an arch of this same type and of almost this exact thickness and span

VIEW ABOVE CONCRETE FLOOR OF COMMERCIAL AND FARMERS' NATIONAL BANK, SHOWING DESTRUCTION OF BUILDING AND CONTENTS.

and weight of metal, which failed because of the slender six-inch posts, and not through the failure of the floor, at the end of three hours and forty minutes' exposure to a 1700 to 2000 degrees Fahrenheit fire.

Further, in the International Trust Company Building a small paper room having a Hennebique floor and ceiling, was so intensely heated that

at the end of three days the lumps of cast iron which had earlier been a copying press and an embossing stamp were still red hot, and yet neither floor nor ceiling show signs of distress. This is the more remarkable in that the walls of the adjoining building fell through the skylights

VIEW OF ROOM BELOW THE CONCRETE FLOOR IN THE COMMERCIAL AND FARMERS' NATIONAL BANK.

upon the Hennebique floor There were in the Commercial and Farmers' National Bank and in the National Bank of Commerce concrete floors, which stood the fire test well.

The general condition of the fire-proof building is such as to indi-

cate to my mind the unfitness of terra-cotta for beam and post covering and floor constructions as were used when compared with concrete or brickwork. Second, there is no evidence that the tall steel building was subjected to an unusually severe test. While it must be admitted that not enough concrete received the full effect of the fire to make the test a perfectly complete one, when I add to this the experience of several years in examining the action of fire upon concrete, I am convinced that had the floors of the Continental Trust or the Calvert Building been of any one of the better class of concrete types and had the beams and posts been encased in four-inch coatings of sound concrete, then renewal would have required little but plastering.

Little difference in the action of the fire on stone concrete and cinder concrete could be noted, and as I have earlier pointed out, the burning of the bits of coal in poor cinder concrete is often balanced by the splitting of the stones in the stone concrete. I never have been able to see that in the long run either stood fire better or worse than the other. However, owing to its density, the stone concrete takes longer to heat through. When brick or terra-cotta are heated no chemical action occurs, but when concrete is carried up to about 1000 degrees Fahrenheit its surface becomes decomposed, dehydration occurs, and water is driven off. This process takes a relatively great amount of heat. It would take about as much heat to drive the water out of this outer quarter-inch of the concrete partition as it would to raise that quarter-inch to 1000 degrees Fahrenheit. Now a second action begins. After dehydration the concrete is much improved as a non-conductor, and yet, through this layer of non-conducting material must pass all the heat to dehydrate and raise the temperature of the layers below, a process which cannot proceed with great speed.

Much has been said about the uncertainty of concrete. The value of concrete in theory is often admitted by those who consider it unwise to use it because of the difficulty of getting the materials properly proportioned, mixed, and placed in position. I have never been able to see the force of this. It is quite as easy to lay sound concrete as it is to put somewhat irregular and confessedly brittle blocks of terra-cotta into place with proper bonding. The main difference seems to be that poor concrete reveals its weakness when it fails on "pulling the centers," while terra-cotta is likely to be strong enough to hold itself in position even when it can do little more. Further, a prolonged search revealed only occasional evidence of temperatures as high as 2400 degrees Fahrenheit, and no instance could be found of real fusion of terra-cotta or brick in them. Occasional evidences of temperature of 2200 degrees Fahrenheit were found, but in general there was ample evidence that the the temperature of the fire in these buildings had never in most places risen above 1700 degrees Fahrenheit. This is likely to happen in almost any office building where little care is taken as to the nature of its contents, and must be provided for if these buildings are to be proof against the combustion of their own contents.

It seems apparent that, with care, steel frame buildings can be so constructed as to stand the destruction of their contents without injury to the steel and probably without danger to the protecting material or floor arches; that, with shutters and wired glass, the burning of more combustible neighbors may be expected to cause little permanent injury to the structure proper; and that a district composed wholly of such buildings would be reasonably immune from danger of conflagration.

On the week following the fire I visited Baltimore and spent the greater part of two days' time in examining the result of the fire on the different types of construction and studying its effects, as far as it was possibe for me to do in that length of time. My conclusions are similar to those of Professor Norton's, and with some slight variations, which would not affect the main body of the report, I heartily approve of the same. I especially approve of that part of the report relating to the advantages of concrete construction, basing my opinion on observations made not only at this fire, but at previous ones which have occurred in buildings of concrete and other types of so-called "fire-proof" construction.

J. P. GRAY, C. E.

THE COMPARATIVE COST OF SLOW-BURNING MILL AND REINFORCED CONCRETE CONSTRUCTION.

By GEO. H. MAURICE, C.E.

The recent completion of several large factory buildings built entirely of reinforced concrete, and the rapidly approaching completion of others, both within the limits of Greater New York as well as in districts outside of the "Metropolitan District," is calling the attention of those interested in reducing the fire insurance risk on factory and mill buildings to the desirability of this form of construction, provided it can reasonably compete with other forms of construction heretofore regarded as standard, in cost, or even come within a considerable percentage of increased cost. Before the dawn of the present era of thin floors of scientifically designed concrete reinforced with steel, the cost of fire-proof floors was prohibitory in anything but the highest grade buildings in our largest cities, where their use was justly demanded by the building laws. Fortunately the time is past when fire-proof floor construction and its attendant expense is limited to the use of a net-work of steel beams supporting brick arches or terra cotta tiles of blocks, and it is well that this is so, for one does not have to look far into the future to see the time when the liberal use of timbers as a material of building construction is limited, by its steadily advancing market price, to the confined uses of interior finish and decoration, where no strength being required, the sizes employed can be cut down to limits set only by architectural considerations. Another great factor influencing the introduction of concrete both plain and reinforced, in place of brick-work, is the serious conditions of labor at present existing in all "organized trades," the high scale of wages and the limit set on the producing power of a union man. The danger or likelihood of sympathetic strikes increases the hazard arising from employing union labor, and it is not surprising that builders should willingly turn to some form of construction which at present is so comparatively free from these dangers. It seems probable that the labor conditions affecting concrete construction will not materially change in the near future, owing to the practical impossibility of organizing common labor, which probably makes up seventy-five to ninety per cent. of the labor charge, after deducting the wages of the foreman. Another very considerable advantage to be expected from the reinforced concrete type of factory building is the freedom from vibration due to running machinery, which is often serious in a tall, narrow building having timber floors.

For the comparative purposes of this article, slow-burning mill construction will be considered as consisting of brick walls 12 inches thick, between pilasters 24 to 30 inches face, supporting one end of the floor beams of heavy timbers, which are usually spaced about 8 feet on centers; the interior pillars, supporting the floor beams, are of timber, from 8 by 8

to 12 by 12 inches in section. The floor itself is of 3½-inch spruce, or 3-inch long leaf yellow pine, depending upon the locality, with ¾-inch hard wood splines. On this is laid three thicknesses of resin-sized paper, mopped with tar, on top of this is laid the wearing floor of 1¼-inch matched maple, preferably, or else Georgia pine. The roof, as usually constructed, is of four-ply felt, tar and gravel, and laid on 3-inch splined plank.

The walls of the reinforced concrete building will be taken as 6 to 8 inches thick between the pilasters which carry the floor beams or girders, varying between these limits with the height. The floor system is designed to carry live loads of 200 pounds per square foot, with a factor of safety of five at six months, thus being about 11 per cent. in excess of that

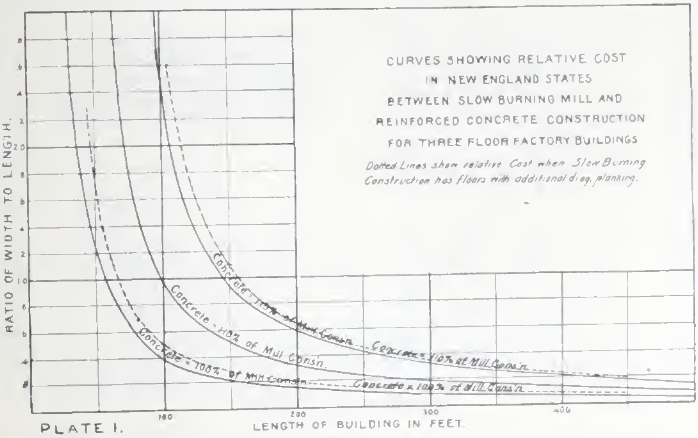


PLATE I.

carried by the slow-burning construction, and thus penalizing the reinforced concrete slightly in our comparisons. For this loading, maximum economy in concrete and steel can probably be secured by using a floor slab of about 4 inches in thickness, including a granolithic finish, this being the thickness assumed for the purposes of the present comparison.

It is impossible to develop general expressions for the cost of buildings of reinforced concrete any more than that of slow-burning mill construction, or other engineering structures, due to the impossibility of obtaining the same economical proportions of column spacing which each individual system would require to suit actual conditions, and the different cost of materials and labor in various sections of the country. However, it is possible to make approximate comparative estimates for certain typical localities, for average column spacing, using empirical formulæ based upon the assumed proportions of the building, as ratio of width to length, number of floors, percentage of wall space taken out for windows, etc., and with coefficients based upon the unit cost of the materials of construction and labor at the proposed location.

The general form of these empirical equations is

$$(a+aR)\ C1+a2R\ (C2+C3).$$

in which *a* is the length of the building, *R* is the ratio of the width to the length, and *C1*, *C2* and *C3* are coefficients depending upon the above considerations, and to be determined for any given locality. By writing one such equation for slow-burning mill construction, and another for reinforced concrete construction, equating them, and solving for *R* we can obtain values of the latter in terms of the length at which the cost of the two different constructions will be the same. In this way the accompanying diagrams have been constructed, as shown on Plates 1 to 4, for buildings of two and three floors, in the New England States, the Metropolitan District, and the Southern Atlantic States.

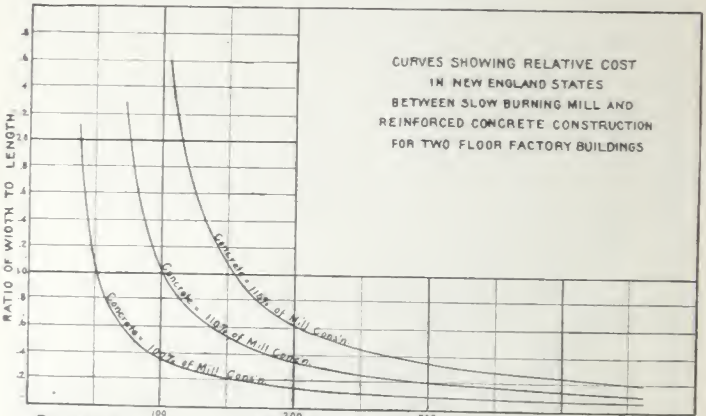


PLATE 2.

In a similar manner, we can construct curves for buildings of such ratios of width to length as will make the reinforced concrete building cost, say 5 or 10 per cent. more than the slow-burning mill construction, which has been done for various percentages of excess cost, and shown on the diagrams as indicated.

Such a floor as described above for the slow-burning mill construction will safely carry a live load of 180 lbs. per square foot, but unless the machinery is so spaced as to come over the floor beams, thus reducing the load on the floor itself, there will be considerable deflection. While the above is considered standard practice, in some of the best mills recently built, a diagonal floor is laid over the paper and tar, and over this the maple wearing floor is then laid, all being well nailed together. This diagonal floor is considered well worth the extra cost as checking vibration in tall buildings, and also reducing the deflection between the floor beams. Should the additional diagonal floor be considered advisable, the relative cost of the slow-burning mill and the reinforced concrete construction for a three-floor factory building in the New England States is shown by the dotted lines in Plate No. 1.

From an inspection of the diagrams, it will be seen that for factory buildings in the New England States, of two and three stories, and of about 250 by 50 feet in plan, of the usual sizes and proportions which may be expected when it is not necessary to meet the special requirements of a given plot in a city, we see that we may reasonably expect the reinforced concrete building to cost about 6 or 7 per cent. more than the slow-burning one, under ordinary conditions, or about 2½ per cent. more if the latter has the additional diagonal floor. In the Metropolitan District, where the relative advantages of the reinforced concrete are largest, the cost may be expected to be about 5 per cent. more, and in the Southern Atlantic States the cost may run up to 25 or even 30 per cent. in excess of the slow-burning mill construction.

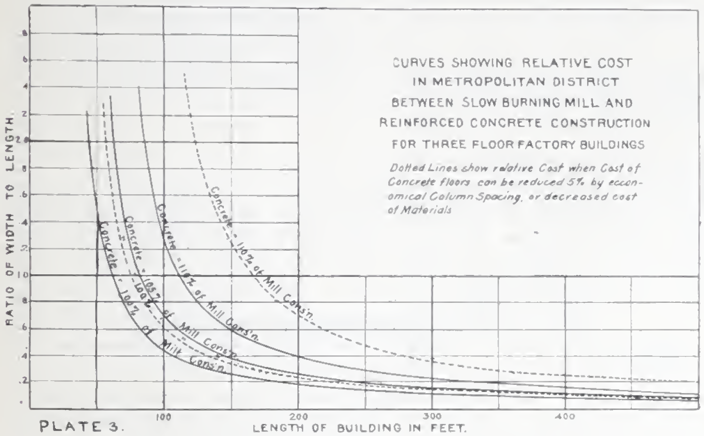


PLATE 3.

It is to be noted that the column spacing for the slow-burning construction is considerably less elastic than for the reinforced concrete, being limited to about 8 feet in a longitudinal direction of the building, while fairly economical results may be had with the reinforced concrete system with column spacing up to 16 feet.

As stated above, the diagrams are based on only a moderate degree of economy in column spacing for the reinforced concrete, in order to take care of the more general cases. Should, however, the layout of the building and the requirements of the floor space be such that an economical system can be used, thus reducing the cost of the floors and columns, say 5 per cent., the cost of this construction, in the New England States, or the Metropolitan District, can be cut down to very nearly the cost of the slow-burning construction, being only about one to two per cent. in excess of the latter, which for the case of the Metropolitan District is shown by the dotted lines on Plate No. 3. If at the same time, it was decided that the slow-burning construction should have the additional diagonal floor, the concrete construction would come out a little ahead.

In this discussion, the price of cement has been taken at $1.75 per barrel, sand at 80 cents, and broken stone at $1.25 per cubic yard. Should the cost of materials drop so that a saving of 5 per cent. on the cost of the reinforced concrete in place could be effected, which has occurred during the past year, we would have the same results, with only average economy in column spacing, as above with an economical system. Should it be possible to secure both of these conditions at the same time the reinforced concrete factory would be from three to four per cent. cheaper than the slow-burning one, besides being more durable, rigid and fireproof.

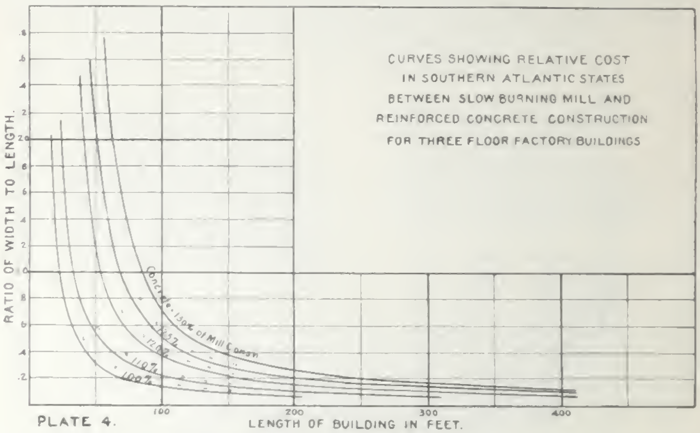


PLATE 4.

It is to be noted that the above comparisons are for the relative cost of the skeletons only of main buildings, covering walls, floors and roof, and do not include glazing or sash for windows, doors, stairs, or elevator shafts, etc. None of these items, it is considered, would materially affect the above results, as their cost would be nearly the same for either form of construction.

CONCRETE CONSTRUCTION.

By EDWARD ATKINSON

Director of the Insurance Engineering Experiment Station, Boston, Mass.

The subject of cement concrete construction has yet attracted little attention from the owners and managers of the large textile factories, machine shops and other works of like kind in this section, owing to the conditions which will be hereafter developed. In dealing with the problem of substituting concrete construction for slow-burning or mill construction, too much stress may not be put upon the incombustible or heat resistant qualities of the material.

In fact the heat resistant and stability of the reinforced concrete when applied to department stores and large warehouses, possess some disadvantages from the point of view of the underwriter which will be disclosed later.

In respect to textile factories, paper mills, machine shops and metal working establishments, the incombustible quality of concrete is of little moment as compared to timber and plank enclosed in brick, because the latter class of buildings have been so carefully guarded and protected that the loss or damage by fire to the buildings has during the last ten years been so insignificant that there is no margin for saving that would warrant an extra cost of construction.

The total loss by fire and water in about a billion dollars' worth of property under my direct or indirect supervision for the past ten years, on buildings and contents, has been six and a quarter cents per hundred dollars insured in one year. Of this a *fraction* over one-quarter of a cent was from leakage of sprinklers without fire, leaving six cents a year or sixty cents for ten years' loss on buildings and contents, mostly on contents. Even in this more than one-half was water damage, leaving less than three cents to fire; and of this again more than one-half was due to damage to contents. Damage or loss by fire to buildings only during the last ten years has not exceeded one to two cents per hundred dollars a year, or ten to twenty cents for the whole term of ten years, in which period many of the buildings, especially storehouses now protected, were without automatic sprinklers.

The principal danger in factories, and yet more in department stores, is from the rapid ignition of the contents. It follows that mills and works constructed of concrete will require to be built on the same rules and protected with fire apparatus to the full extent now called for in slow-burning construction.

The rules in construction are:

1st.—The separation of each floor from every other without belt holes, ducts or shoots.

2d.—Stairways, elevator shafts, water closets and sinks, and passage ways for belts, ropes or wires, each if possible in separate towers or

within incombustible walls, with all doorways or other openings at floors guarded by automatic fire doors. Skylights glazed with thin, quickly breakable glass (wire mesh underneath to catch fragments) to give quick vent to heat, flame and smoke.

Every room with rare exception to be protected with sprinklers and the whole establishment guarded by the customary equipment of pumps, pipes and hydrants, amply supplied with water.

A few words on how not to construct a so-called fireproof building unless the object is to assure the complete combustion of the contents and the largest damage by fire in the building.

Do not make an open stairway from lower to upper story, surrounded by galleries fitted with combustible goods. This method has already assured the complete combustion of very large and valuable stocks of goods in several instances, whereas had the buildings been of combustible material they would have fallen at an early stage of the fire, massing the goods below with large salvage to the underwriters.

Do not put a wooden flue 12″x9″ from basement to the top story of an incombustible building without any vent at the top, in which to carry electric and telephone wires, unless the purpose is to carry fire to every floor, especially to top story, causing damage by fire and water to about thirty thousand dollars ($30,000) where by the simplest precaution the loss might have been one hundred dollars ($100). An example of this method has lately been disclosed in Boston.

Do not fill an incombustible building with wooden varnished partitions, wooden shelves and wooden counters, covering goods underneath, unless the object is to prevent the water from sprinklers reaching the fire, thus calling for the minimum of water damage from hose streams.

When buildings are constructed of re-enforced concrete, finished within with alignum, uralite or other incombustible finish and doors, and glazed with wired glass set in metal sash, so that there will be no wood in the building—then fitted within with metal shelvng and counters, and furnished with desks and chairs of incombustible material, the maximum of safety will be attained and the protection of the contents will be assured by suitable appliances.

This may seem to be a fancy or visionary picture, but even from the partial investigation which I have made on these several points of construction, finish and furnishing, I feel well assured that the time is not far distant when this full measure of safety will be attained at as low a cost, or even at a less cost than the present methods of mill construction, finishing and furnishing.

Cement concrete has already displaced wood in part and may soon wholly displace it in the wet departments of paper mills, print works, bleacheries and dye works, where the vapors, often chemically charged, are very destructive to wood.

In dealing with this class of buildings regard must be given to the tendency of these volumes of vapor to condense on walls and on the under side of roofs of which the material is a good conductor of cold.

The roof of a paper mill in the machine department, of print works and of other buildings, subject to be filled with great volumes of vapor,

must be of such non-heat conducting material that the heavy volumes of vapor may be removed by adequate ventilation without condensation. In a roof in part of wood this cannot be provided by air spaces because the humidity penetrates these hollow air spaces, there begins the decay. These roofs are usually made of four-inch plank grooved and splined, one-inch sheathing boards underneath nailed solid, one-inch of lime mortar, one-inch top board and then five-ply composition roof.

If concrete is a better conductor of heat and cold than wood, then suitable provision must be made to retard the passing of heat and cold, not only through the walls, but above all through the roof. It may be that suitable roofs may be made of concrete blocks, but this is a part of the unsolved problem now submitted to concrete construction companies and makers of cement.

This communication relates only to the isolated factory and workshop risks which are substantially free from neighborhood hazard, never in the crowded and congested commercial districts of cities.

I need not point out what a barrier buildings made wholly of incombustible materials and glazed with wired glass (so made as to give the maximum of diffusion of light within) would be to the spread of conflagrations in cities or what a vantage point the flat roofs would be for overhead hydrants and water supplies in extinguishing fires in the neighborhood of such buildings.

CONCRETE DWELLING HOUSES

Another wide field for the use of cement concrete must be in the construction of detached dwellings. It is already established at an alleged cost less than brick, upon the hollow block system; why not in monolith?

An ideal dwelling combining safety and the best hygienic conditions would consist in a house set up above grade sufficiently for drainage, without cellar which is apt to be unwholesome. The first floor of asphalt concrete, which is non-heat conducting, warm to the feet and impervious to moisture; the superstructure of cement concrete, one or two stories with flat roof, roof to be partly glazed in winter or enclosed in wire mesh in summer; the roof a play space for children when the ground is wet. Open fire-places in every room and the hot water heater for winter in an ell or annex. A cold room in the ground outside or underneath the ell.

In the south, constructed on the plan of Eastern hot countries, with a patio or wide open porch between the living rooms and the kitchen and offices,—three sides of a quadrangle with garden within facing the south and open to the sun.

In the kitchen an oven can be built into the wall of metal separated by a heat chamber of two inches around the inner metal oven, surrounded by the non-heat conducting concrete walls. Under this metal oven a Rochester lamp may be placed without any fuming into the inner oven. In such an oven 18" wide, 16" high and 14" deep, meats, vegetables and bread may be roasted, baked, simmered and stewed. One quart of oil burning eight hours will cook supremely thirty (30) to forty (40) pounds

of food,—meat, fish and vegetables at the same time; but as the heat is uniform and moderate the juices are not distilled and no bad odors are generated, no flavor passing even from onions to custard pudding when cooked on the same shelf. This is the principle of the Aladdin oven. Information on the portable Aladdin oven invented by the writer may be had by addressing Aladdin Oven Company, Brookline, Mass. The writer has no commercial interest in it.

Alongside the oven in the same recess a broiler for quick work with charcoal or bog fuel. Next a small heater for boiling. With this apparatus in a recess flush in front with the kitchen wall, no range or cooking stove will be needed, the abominations of the American frying pan will be discarded and dyspepsia will be abolished.

WAREHOUSES FOR COTTON.

This enterprise demands warehouses of incombustible material, divided into sections or pockets to contain not over one thousand (1,000) bales each, stored on end and not piled in mass. Such warehouses will then correspond to the best and safest now built in connection with textile factories for the storage of cotton, wool, jute and hemp.

Concrete will be the safest and cheapest material for this service. Such warehouses may be placed where land values are low, space ample and railway tracks readily provided on both sides of long ranges of such pockets of a thousand bales each. The floor space required for one thousand (1,000) bales with suitable alleyways would be about eight thousand (8,000) square feet in one pocket, of which five may be placed side by side with party walls between, parapetted above the roof, on less than an acre of ground. The office buildings could be placed on the excess of space in the acre with the pump, pipe, hydrant and tank service.

The cost of sprinkling apparatus would vary according to the conditions, but would be very small compared to the security given and would be necessary to the negotiations of permanent insurance to the capacity of these storehouses, so arranged that each warehouse receipt would also carry the guarantee of strong insurance companies covering the risk of fire to the measure of the capacity of the building. The insurance would then be procured at a very trifling cost.

It would be well for you to submit these general suggestions to a concrete construction company for working out the details and the cost.

IN CONCLUSION.

It now seems to be proved that large works may be constructed of re-enforced concrete within ten per cent. or less of the cost of slow-burning construction.

That such buildings are not subject to as great vibration from high speed machinery, or heavy slow movements.

That dwelling houses can be constructed of concrete at less cost than of brick.

That large warehouses may be constructed at low cost combining the maximum of safety with durability.

Such are the apparent conclusions which the writer has derived from the reports of tests and the statement of facts submitted by the large construction companies, each on its own behalf.

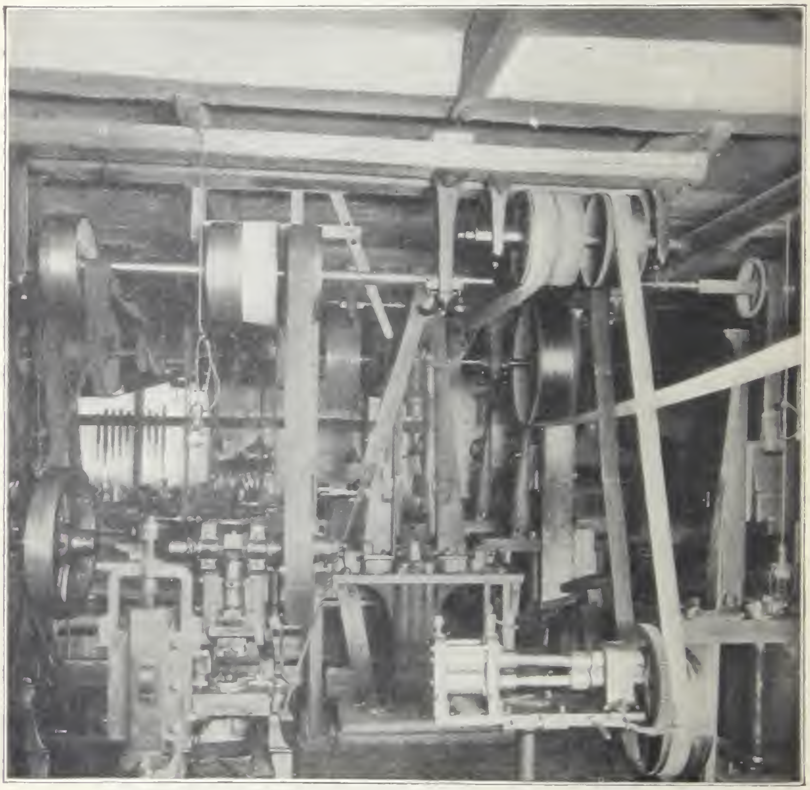
On the other hand, many statements have been made of the alleged collapse of concrete buildings. These have been examined so far as they could be secured and only three alleged accidents in concrete buildings of modern design and construction called for any attention. One was found to be due to piling excessive weights of merchandise on a concrete floor which had been designed for light mechanical work. One was found to be due to an effort to copy a scientific method without authority and without regard to any of the rules, conditions or stresses.

The last was the collapse of a floor in a school building in which the cement was setting very slowly and from which the supports were taken away too soon. After it was restored and had time to harden the floor stood a much higher test than had been called for.

Whether or not these conclusions which have been derived from "ex parte" statements will be fully sustained in all particulars, may be proved during the next six months by the investigations and tests proposed on the part of the undersigned by the Insurance Engineering Experiment Station if that undertaking is fully sustained by the representatives of this art.

THE SEARCHING TEST OF A LIGHT FACTORY FLOOR.

In the discussion raised by Mr. Atkinson's very interesting questions, on vibration, an effort has been made to furnish illustrations from as many divergent examples as is possible. It might seem at first blush that the very light floor construction in the Richardson Building in Newark does not furnish as extreme an example as might be found. The writer presented this view to the Editor of the Cement Age, who met it with the augument that to confine the illustrations to the extremely heavy class of work, would not form an adequate answer to the questions under discussion.



THE MACHINERY OF ONE CORNER OF THE 5TH FLOOR OF A NEWARK FACTORY. THE FLOORS ARE OF CONCRETE REINFORCED WITH CLINTON ELECTRICALLY-WELDED FABRIC.

The Richardson factory is a six-story and basement building, all of which is used for manufacturing purposes. The entire building is thoroughly fireproof, and the plans to ensure this end embody the ideas of Mr. Howard Constable, the well-known fireproofing expert. The floors are of the full bay type; they are of cinder concrete reinforced with Clinton electrically-welded wire fabric of 4x12-inch mesh, 8 and 11 gauge galvanized wire. They are 6 inches thick and the plan of reinforcement was that two thicknesses of the fabric were used—one being placed lengthwise of the building, and the other at right angles to the first.

These floors, which were laid some 5 years ago, were among the earlier installations of this type of construction. Critics were not lacking who predicted dire calamity. The owner heeded these warnings to the extent of ordering a vigorous test. Three panels of the floor were erected, and while it was, of course, very far from its final strength, the centre bay was tested with a load of sand to the extent of 290 pounds per sq. ft. This was left for twenty-four hours. During the night a driving rain fell on the sand, and while there were no means of measuring the increased weight, it was estimated that the load must have increased at least 50 per cent., the total deflection under this combination of unfavorable conditions being less than $\frac{3}{8}$ of an inch.

After the building was complete, it was found necessary to move a six-ton safe the entire length of the building. The greatest deflection noted was less than 3-32 of an inch.

The illustration showing the machinery on one corner of the fifth floor is typical of the machinery installed throughout the building. Beside the dye-sinking machines, one of which is shown in the foreground, attention may be called to the four drop hammers. One of these is placed almost in the centre of the bay. The drops weigh from 100 to 150 lbs. and the height of the fall is from 3 to 4 feet.

It seems unnecessary to enlarge on the vibration strains which such machinery must cause. Although the floors have been subjected to several searching examinations, absolutely no traces of cracks have been found after five years of the strains above described.

With many of these drops in operation on the various floors, the vibration is scarcely noticeable.

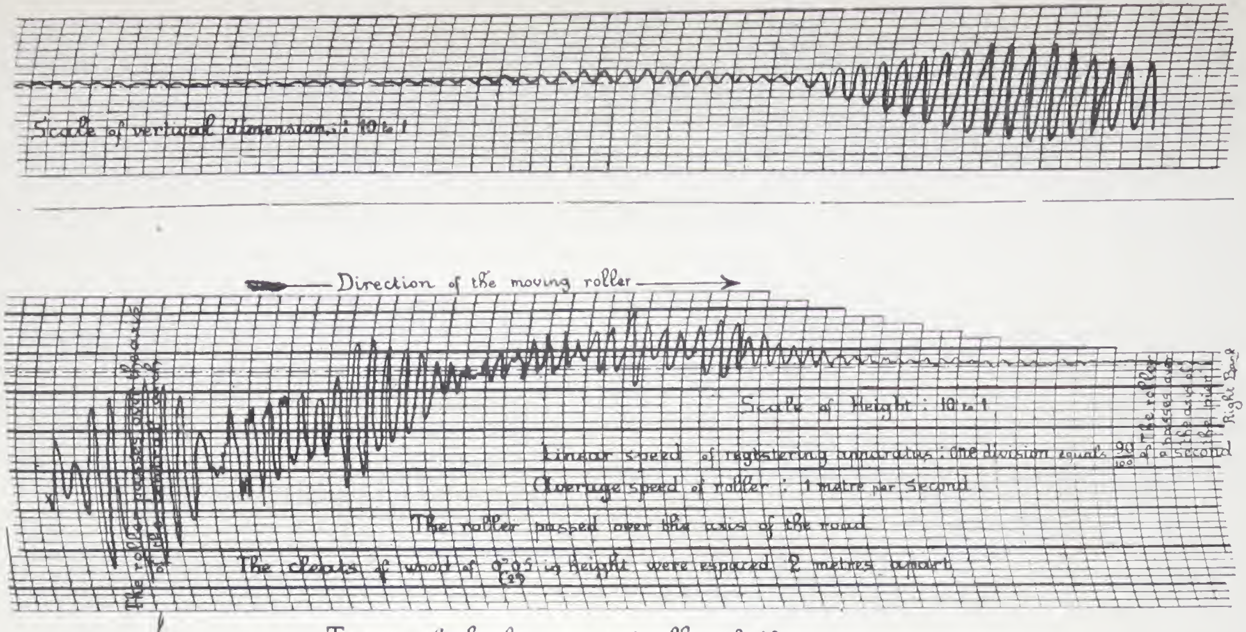
A REMARKABLE SERIES OF VIBRATION TESTS.

The time has gone by when it is necessary to answer questions as to the ability of reinforced concrete to withstand vibration strains with theoretic formula. So many practical demonstrations have been made that the only difficulty in answering is to select one example from the accumulated mass of data.

The tests made with moving loads on the reinforced concrete bridge at Chatellerault Vienne, France, are an absolute necessity to the vibration question. This bridge, entirely built of armored concrete, Hennebique system, has three arches, the two side arches being 131′ and the central

THE QUICK STEP TEST.

one 164′, the rise of each being one in ten. Its essential parts are arches of armored concrete carrying the road bed by means of small posts of armored concrete. These posts are 6″ square. The piles and abutments are also of armored concrete. The foundations were very simple, the bed of the river being of solid rock. Work was begun on the 15th of August, 1889, and the rough work on the bridge was finished on November 5th of the same year. The bridge, therefore, took 80 days in the building. The woodwork in the center of the arches was taken out on December 15th, or four months after the beginning of the foundations. The tests were made at two different times, first with stationary loads, using for that purpose about 6,000 lbs. of sand, and, secondly, with moving loads. The two most interesting features of the moving-load test were made with the 16-ton steam roller in one case and with a company of infantry, 250 strong, in the other. The roller was run back and forth across the bridge. The deflections under these conditions are indicated in the following table.



Tests of shocks by means of roller of 16 tons
Diagrams registered at key of central arch under the down water central arch

LATERAL ARCH, RIGHT BANK.

Maximum deflection	0.5-16″
Maximum rise	0.3-16″
Total maximum vibration	0.8-16″

CENTRAL ARCH.

Maximum deflection	.1-16″
Maximum rise	1.2-32″
Total maximum vibration	3.2-32″

LATERAL ARCH, LEFT BANK.

Maximum deflection	0.9-32″
Maximum rise	0.15-32″
Maximum total vibration	1.05-32″

On the road wooden strips 2″ high were placed at right angles to the direction of travel of the roller. These strips were spaced 6′ apart, and over them the roller was driven, giving a series of successive shocks.

The other test, though of a different nature, was equally remarkable. When it is considered that it is a canon of military law that infantry in crossing a bridge must break step, the test of having 250 soldiers cross this bridge in step and at double-quick time assumes its true significance. The deflections under these conditions follows:

Maximum deflection	7-32″
Maximum rise	1.2-32″
Total maximum vibration	8.2-32″

DOWN-STREAM CENTRAL ARCH BEAM.

Maximum deflection	7-32″
Maximum rise	2-32″
Total maximum difference	9-32″

UP-STREAM CENTRAL ARCH BEAM.

Maximum deflection	7-32″
Maximum rise	2-32″
Total maximum difference	9-32″

UP-STREAM LATERAL SIDE ARCH BEAM.

Maximum deflection	5-32″
Maximum rise	2-32″
Total maximum difference	7-32″

In conclusion, it may be said that in every case the bridge after the load had been taken away resumed its initial position immediately and totally. A careful examination of the arches did not show any signs of cracks either during or after the tests.

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